IoT Enabled Wireless Health Monitoring System Using Textile Antenna

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***Abstract* — Health monitoring systems have predominantly been in the limelight in recent years. This progressive field has seen innovative approaches and breathtaking features introduced by means of the Internet of Things (IoT). This paper takes a step forward as an effort to prioritize user's comfort incorporating Wemos D1 Mini and Textile Antenna, ruling out the possibility of forgetting the wearable at home. This essentially introduces how sensors clubbed with a textile antenna could be the new face of IoT in the coming years. The health parameters, including heart rate, pulse rate and body temperature, can conveniently be accessed by the guardian through an application designed exclusively to take immediate action. The project's testing phase delivered coherent results with the textile antenna fixed on the patient's outfit. With the successful deployment, the concerned doctor could receive unhampered notifications about the patient's health condition without further ado.**

Index Terms — IoT health monitoring system, Textile antenna, Wearable health tracking, Arduino

I. Introduction

Technology has bred several gadgets and the advancement of such gadgets has had an optimistic hope lit for the generations to come. With innovative approaches mounting in the domain of electronics, what was not possible before, is technologically possible today. This era has not only paved the way for technology to demonstrate its miracles but has also gotten us cornered to newer diseases and vulnerable to the contaminated environment. Failures are encountered when sufficient care or attention is denied to patients, either because of having the hospital fully occupied or due to the lack of necessary equipment. In many cases, when the patient is left unattended, a delayed medical treatment does no good, in fact, the case rather gets intensified.

Healthcare must remain as the topmost priority of any individual. The advent of health monitoring systems sure has banged the doors, moving towards a better and healthier society. However, the rates of building or buying these systems weigh higher than the affordability of the citizens of developing nations.

This project in the field of IoT brings forth the possibility of tracking health parameters like heart rate, body temperature and pulse rate in an effective way using textile antennas [1]. It helps in monitoring the health of the bearer anytime and anywhere. Once the doctor gets access to the health parameters of the patient, the recorded physiological parameters can help in scheduling appointments instantly in case of critical cases. This also rules out the inconvenient and time-consuming routine checkups at the clinic. This paper will thus deal with acquainting different health parameters while analyzing the existing health monitoring systems. It also aims at improving and fulfilling the drawbacks of the same.

The backbone of this revolutionary idea is the Internet of Things. The system of interrelated computing devices or simply IoT fuels the project with the ability to transfer data over the network without requiring human to human or human to computer interaction. Transmission and reception of data are easier with the Internet of Things. Here, the sensors, Textile antenna and Arduino are part of the connected network.

II. Architecture

The proposed system is summed up in Fig. 1, based on the integration of the antennas and sensors collecting data from the environment, and in this case the patient's physical parameters.

Fig. 1. System overview.

The measuring unit comprises Wemos D1 Mini connected to the ECG sensor, accelerometer and temperature and humidity sensor. As the sensors get activated due to the respective changes in the state of the patient's body, real-time data is sent to the cloud via internet is connected using the wearable textile antenna planted on the patient's outfit as shown in Fig. 2.

The data is stored and updated in real-time in the cloud. The specialist can then work on this data to predict health conditions or attend the patient in case of emergencies. This data can also be viewed seamlessly on an application or a website application, based on the guardian's preference.

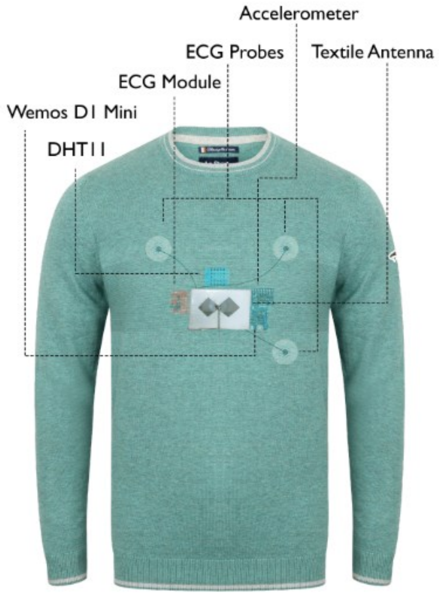
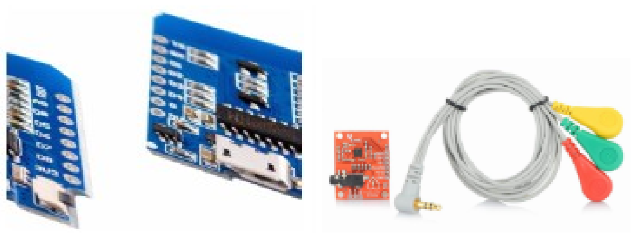


Fig. 2. System model.

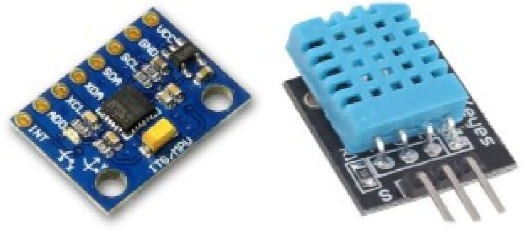
III. Hardware Description

The system comprises a Wemos D1 Mini as shown in Fig. 3(a), a tiny microcontroller with WiFi capabilities enabling transmission of data collected by the sensors. This board is much similar to an Arduino board with WiFi capabilities, which is also compatible with the Arduino Integrated Development Environment (IDE). It hosts 11 digital I/O pins and 1 Analog input pin. By being the fully-fledged development board, programming is simpler with no additional hardware.

The ECG sensor, accelerometer sensor, DHT11 temperature and humidity sensor as shown in Figure 3(b), (c) and (d), respectively, work together to consolidate patient's health parameters. These readings are collected and sent to the Wemos D1 Mini microcontroller.



(a) (b)



(c) (d)

Fig. 3. Components used in the prototype (a) Wemos D1 Mini (b) ECG sensor (c) Accelerometer (d) DHT11 Temperature and humidity

Wearable antennas made of textiles are the most comfortable form of devices. The development of textile diamond dipoles that operates at 2.45GHz is used in this project. It's for flexible fabric antenna that can be easily attached to clothing. These antennas are flexible, lightweight, and are perfect as ubiquitous computing equipment, integrated into our personal everyday wear. The textile antenna supports communication capabilities by transmitting and receiving WiFi signals. This antenna is planted on the user's clothing, which makes it absolutely comfortable to the user.

IV. Software Overview

The main microcontrollers present in the actuation unit and sensor units require software to handle hard real-time tasks efficiently. Also, since the system is a part of the Internet of Things (IoT), it is important to have it connected to an online database to store and retrieve data. The sensor unit has a real-time software to obtain heart activity values from the user's body using sensors. It categorizes the data and uses the communication unit to properly transfer the data to the actuation unit. The software unit in the actuation unit is far more complex than the sensor unit. Since this unit is responsible for responding in case emergencies arise, it is also responsible for recording the data from the wearer and transferring them to a cloud database in real-time to enable IoT activities.

Firebase is used as the real-time cloud database discussed above [2]. It provides web or mobile developers with a plethora of tools and services as Google's mobile and app web development platform. Firebase not only provides a real-time database to the developers but also caters them additional features like Authorization, Crashlytics, Performance monitoring, Crash reporting and so on. Here, it is used to store the health parameters of the user like body temperature. This gets accessed by the concerned doctor in charge later.

The other part of the software will be the mobile application through which the data from the sensor unit can be accessed and notifications can be received. Such an application was developed using Android Studio. Anyone with credentials can view the concerned wearer's data through the mobile application. For example, a doctor can view historic data of the information collected to quickly diagnose the patient. Overview of software components used in the project as illustrated in Fig. 4.

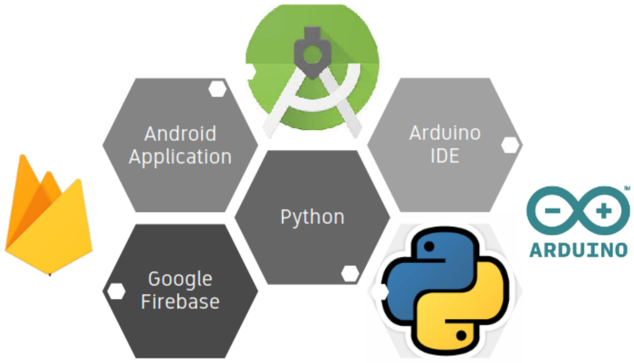
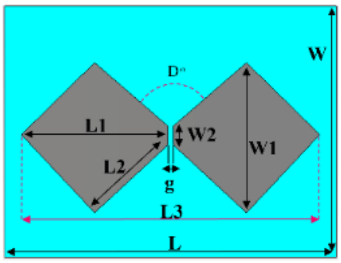


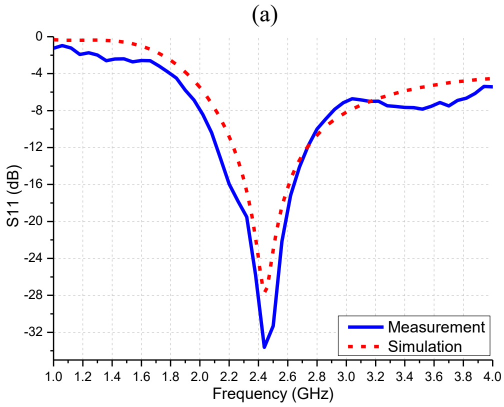
Fig. 4. Software components used in the prototype

V. TEXTILE ANTENNA

In this paper, a wearable antenna in [3] is used as a transmitting device in the proposed IoT system. The antenna in [3] is designed to operate at 2.45 GHz. The diamond dipole is chosen to be included in this system because of the performance that is better than a conventional dipole antenna. Diamond dipole design is an inverted bow-tie dipole. It also offers a broader bandwidth as opposed to conventional planar straight dipole [3]. The overview of the antenna design, S_{11} and radiation pattern results are shown in Fig. 5.



(a)



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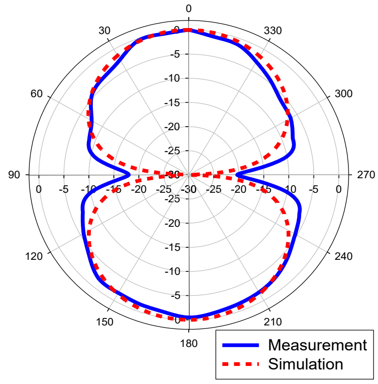
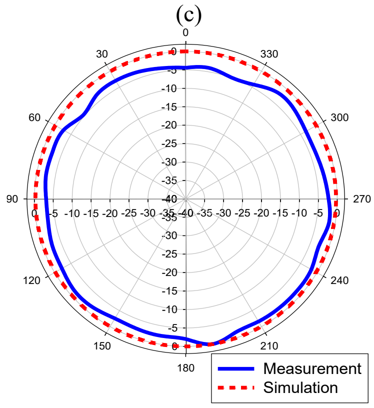


(c)



(d)

Fig. 5. Textile antenna in [3] (a) design (b) S_{11}; radiation patterns at 2.45 GHz (c) E-plane (d) H-plane.

As mentioned in [3], the return loss depth is -33.64 dB at 2.45 GHz while the measured bandwidth is 750 MHz ranging from 2.05 GHz to 2.8 GHz. The measured gain for the 2.45 GHz diamond dipole is 3.09 dBi. Overall, the simulated and measured results are in good agreement. The antenna is working well at 2.45 GHz, making it a suitable transmitting device in the proposed system. The antenna prototype is shown in Fig. 6. Pigtail SubMiniature Version A (SMA) connector is used in this prototype.

Fig. 6. Prototype of textile diamond dipole antenna [3].

As the textile antenna will be embedded in the patient's body or cloth, bending and wetness conditions have been investigated too. These conditions are discussed in [4]. As shown in Fig. 7, bending measurement has been performed in a horizontal orientation. As mentioned earlier, the measured S_{11} value at normal conditions is -33.64 dB. Meanwhile, under the bending condition, the measured S_{11} value depth is -29.6 dB at 2.45 GHz. Radiation patterns obtained under the bending condition are closed to flat conditions. Therefore, it is proved that under the bending condition the textile antenna is still working well.

Fig. 7. Bending condition measurement [4].

Under wetness conditions, the textile antenna is being tested in three different situations. The first one is completely wet, the second situation is damp and lastly, it is a dry situation. The textile antenna was soaked in water to be tested in wetness measurement as shown in Fig. 8. As discussed in [4], the antenna is predicted to not working well in a complete wet situation. The S_{11} result shows the resonant frequency shift of the antenna to approximately 1.6 GHz. The significant frequency shift is mainly due to the high-water permittivity that affects the antenna performance. Meanwhile, in a damp situation, the antenna frequency is shifted to 2.37 GHz with an S_{11} value of -27.3 dB. In a dry situation, the initial performance has been retrieved and the antenna is working well at 2.43 GHz with S_{11} value of -32.6 dB.

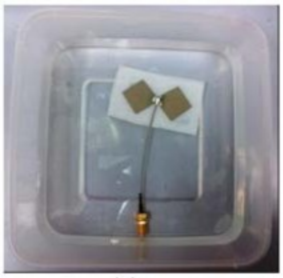


Fig. 8. Wetness condition measurement [4].

VI. Working Principle

The working of the project is a simple process. The Wemos D1 Mini is programmed to obtain real-time raw data from the sensors connected to it. The raw data is processed to obtain meaningful information and is uploaded in real-time to the cloud-based database via the internet. The internet connection is via WiFi which is enabled by the textile Antenna.

VII. Testing and Results

This project aims at retrieving the health parameters of the patients or users effectively when there is a change detected by the system and it accomplished just that. The ECG sensors, accelerometer and the temperature and humidity sensor collect data as health parameters, recorded as variables by the Wemos D1 Mini. The prime feature of the project, the textile antenna is embedded in the patient's outfit that sends real-time data to the cloud via WiFi signals. Fig. 9 shows the prototype of the proposed system hardware that is planted on the patient's outfit.

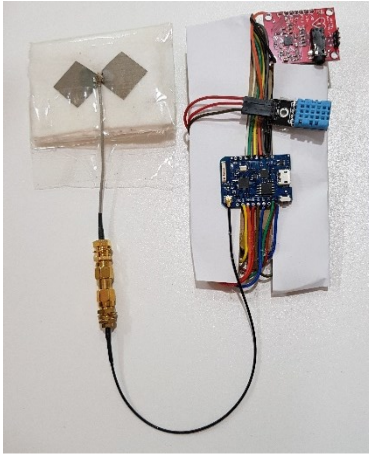


Fig. 9. Prototype of the Wemos D1 Mini, sensors and textile antenna

Wemos D1 Mini, being the main microcontroller acted as a bridge between the hard data and the storage of the same in the real-time database. The system used Firebase for the purpose of storing dynamic data. A project was created and linked to the Android application developed. The Firebase console of this project is shown in Fig. 10. The transmitter will transmit the data and store the data in the Firebase cloud database using the Wi-Fi connection on the server-side.

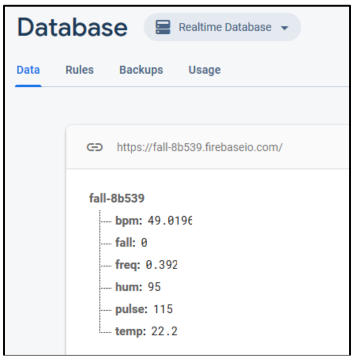
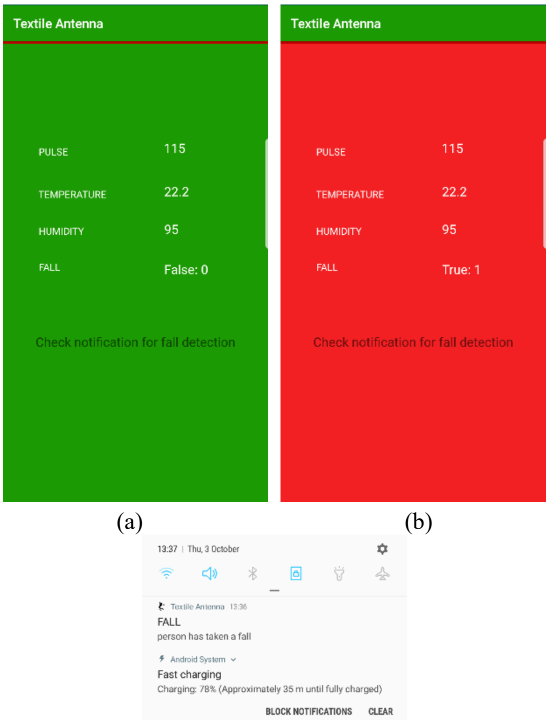


Fig. 10. Firebase console.

The mobile application was designed to have its display color change according to the type of alert. If the wearer's health parameters fall below or above the normal threshold rate, the display turns red and otherwise stays green, as in Fig. 11 (a) and (b). This facilitates the guardian to instantly know if there is an emergency, without knowing the normal threshold rates of the respective health parameters. This feature fills yet another gap, of a guardian's unconsciousness when he/she does not pay attention to the patient's level of emergency. Apart from this, notifications add to the strength of this app, in Fig. 11 (c), ensuring the guardian is most definitely informed of the patient's health condition in case of a fall or harmful heart rate fluctuation.



(a) (b)

(c)

Fig. 11. Color change in display according to the alert and notifications received (a) in normal situation (b) fall situation (c) apps notification for fall situation.

The picture above presented results show that a complete prototype has been successfully tested. Coherent real-time health parameters including heart rate, pulse rate and body temperature have been retrieved through IoT when deployed on the wearer. Fall alert notification also has been successfully deployed and tested in the proposed system. The health parameters are stored and updated in real-time in the cloud which is useful for the guardian or doctors to monitor the patient's health condition.

VIII. One-Board Design

For serving the purpose of the project to its fullest, all the individual entities must be packaged in the simplest way possible. For this reason, a custom PCB was designed to house all the sensors and the Wemos D1 Mini board as shown in Fig. 12. The two-layered circuit board is 8 cm x 4 cm in dimensions making it extremely portable and convenient for usage in most of the situations. All the sensors will be mounted to the PCB along with the Wemos D1 Mini. The Textile Antenna will be connected to the Wemos D1 Mini. The custom PCB also features power channels for 3.3V and 5V as some sensors require either of these voltages. Power is provided to all the components using a battery pack, like a small 5V LiPo rechargeable battery.

The system comprises of a Wemos D1 Mini, a tiny microcontroller with WiFi capabilities enabling transmission of data collected by the sensors. This board is much similar to an Arduino board with WiFi capabilities, which is also compatible with the Arduino IDE. It hosts eleven digital input/output (I/O) pins and one Analog input pin. By being the fully-fledged development board, the programming is becoming uncomplicated with no additional hardware.

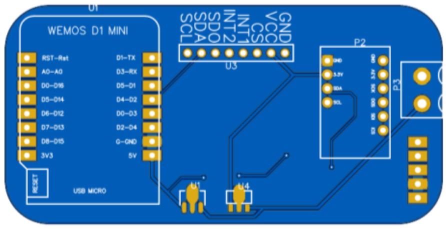


Fig. 12. One-board design.

IX. Uses and Applications

For the patients who dislike periodic appointments with doctors and for the busy doctors who find it chaotic to track the health conditions of discharged patients, this Health monitoring system is a lifesaver. It, being an efficient system to monitor the physiological parameters of the body, is a user-friendly health tracker thanks to its wearable textile antenna. The tracker keeps the guardians updated on the patient's health, minimizing the time-consuming scheduled appointments.

It is possible to have the system conform to outdoor patient monitoring when he/she drives a vehicle and emergencies arise. The driver is assumed to have the textile antenna-integrated system on his/her outfit, instead of a wearable that can be easily forgotten to equip. In case of a near heart attack condition, the motion of the vehicle can be controlled as an improvisation. The location of the patient can be sent to the guardian along with mechanic calls to ensure the guardian is not uninformed of emergencies.

Old aged patients who suffer from dementia especially benefit from this system. They tend to forget wearing or carrying a smart device. The fact that it's planted on the dress accounts for this shortcoming. The unwillingness to consult a doctor can also be compromised with a system that takes care of their needs just as better as a doctor. In addition to these features, geofencing can be included as an activity in the mobile application in case the patient wanders out of the geofence.

Moreover, it is convenient for the doctors to keep a record of the health reports of various patients through an application. Such an application can be similarly designed to check if there are any emergencies based on the color code discussed above to assess a group of patients at the same time.

X. Conclusions

IoT enabled health monitoring system using the textile antenna is presented. By incorporating wearable textile antenna, Wemos D1 Mini, sensors and mobile application, a comprehensive IoT system is created to benefit the users. A complete prototype has been tested and successfully deployed. Coherent results when the textile antenna fixed on the patient's outfit have been obtained. Through successful deployment of IoT, the health parameters, including heart rate, pulse rate, body temperature and fall alert, can be retrieved by the guardian via an application to take immediate action.

For future work, a one board custom PCB will be fabricated to house all the sensors and the Wemos D1 Mini board to have a more compact prototype that is suitable to be used in daily attire. As for the textile antenna, the wetness issue can be addressed by using waterproof fabric or coating. The system is suitable to be used in many applications apart from healthcare. The sensor can be replaced according to the desired application.

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